SPIRAL FLUX COMPRESSION GENERATOR (FCG) BASED SELF-CONTAINED PULSED HIGH VOLTAGE SOURCE

Yu. Tkach, V.Dynashev, V. Kolesnik, V. Hristenko *Institute For Electromagnetic Research Ltd.*, Pr. Pravdi 5, Kharkiv, Ukraine 61022, **S.A.Mironenko** *State Foreign Trade Enterprise "SpetsTechnoExport"*, 7 Moskovskiy Av., Kyiv, Ukraine 04073, **L. Altgilbers** *USASMDC/ARSTRAT*, P.O. Box 1500, Huntsville, AL 35807, USA; **Ya. Tkach** *Gomez Research Associates Inc., 4835 University Sq., St. 19, Huntsville, AL 35816, USA*

Abstract

The design of a self-contained, high-voltage power source, based on a spiral FCG, is described. The diameter of this multi-sectional spiral coil is 50 mm. The external diameter of its aluminum alloy armature is 26 mm with wall thickness of 2 mm. The liner is filled with cast and hot-pressed high explosive (HE) pucks. w A 32 J capacitor is used to seed the magnetic field in the FCG's spiral coil. The seed source capacitor's charge voltage is used to control the initial FCG energy. The operational seed source charge voltage is 30kV. The spiral FCG drives a pulse forming-unit, containing an inductive storage unit, an explosive wire opening switch, and an output spark gap. This 143 mm diameter and 600 mm long self-contained, pulsed energy source has the following output specifications: output voltage of 450-500 kV and electric energy in the pulse of 1200 J.

I. INTRODUCTION

There is an urgent need for self-contained pulsed high-voltage sources for driving different types of devices. In our view, the most prospective pathway to their development is the use of spiral FCGs with small diameter spiral coils (40-50 mm). As noted [1,2] further decreases in FCG spiral coil diameter causes substantial output deterioration. In this paper a self-contained pulsed energy source is described. It is based on a spiral FCG design with the following characteristics: spiral coil diameter 50 mm, coil length 250 mm, 7 sections, external diameter of the aluminum armature 26 mm, voltage pulse magnitude 500 kV, energy in pulse 1200 J, and overall diameter 143 mm and length 600 mm.

II. A HIGH VOLTAGE SOURCE DESIGN

A Block Diagram of the self-contained voltage source and its general view are shown in Figure 1 and Figure 2.

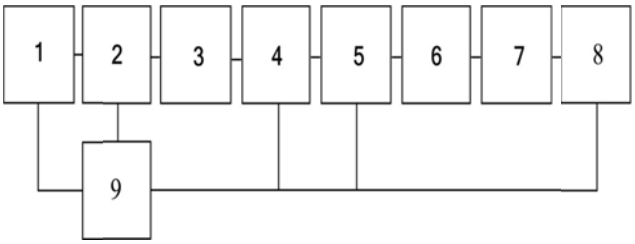

Figure 1. Block diagram of pulsed high-voltage source based on spiral FCG: 1 is battery, 2 is DC-DC converter, 3 is capacitor storage; 4 is explosive closing switch; 5 is spiral FCG; 6 is inductive storage; 7 – exploding wire opening switch; 8 output spark-gap; and 9 is the synchronization and control circuit.

Figure 2. General view of self-contained voltage source

A. Spiral FCG

This spiral FCG's distinction is the use of a high-voltage (output voltage 30 kV) capacitive seed source to provide the initial magnetic field. Using these high voltages permits one to substantially reduce the required capacitance and capacitor size, which, in turn, reduces the overall voltage source dimensions. This approach, however, requires the implementation of additional measures to improve the electric strength of all energy source elements, especially the spiral FCG. A schematic diagram describing an FCG with a coaxial load is shown in Figure 3.

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14. ABSTRACT
The design of a self-contained, pulsed high voltage power source, based on a spiral FCG, is described. The diameter of this multi-sectional spiral coil is 50 mm.

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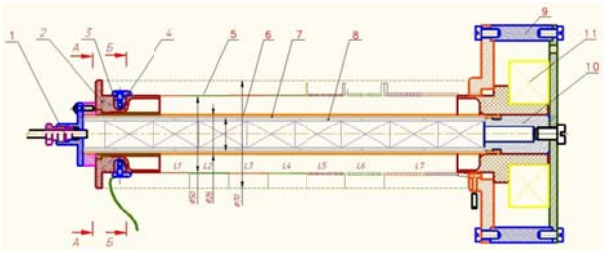


Figure 3. Design of FCG with a coaxial load: 1 - detonator unit; 2 - detonator and crowbar attachment flange; 3- crowbar insulator; 4 -crowbar external ring electrode; 5 - sectioned spiral coil; 6 - armature with dielectric coating; 7 - dielectric tube; 8 - HE pucks; 9 - outer conductor of coaxial load; and 11 - current transformer

The FCG spiral coil has an internal diameter of 50 mm, a length of 250 mm, and is divided into seven sections. The coil is wound using enamel wire with additional Teflon tape insulation. The coil is coated with a thin layer of epoxy and covered with glass tape to increase the mechanical strength. This coating also serves as an inertial mass. The internal diameter of the coated spiral coil is 70 mm and its length is 250 mm. The measured inductance of the spiral coil was 384 µHn.

The armature is made of heat-treated aluminum alloy, coated with a thin insulation layer, and has an outer diameter of 26 mm and a wall thickness of 2 mm. The liner is filled with cast and hot-pressed HE pucks. The puck diameters are 19 mm and their length is 30 mm. The pucks are inserted in organic glass tubes and after which they are inserted into the armature. This design feature provides correct centering of the pucks inside the armature and the equilibration of the explosion product's pressure on the armature walls. These FCGs were tested with 30 nHn loads, with a calibrated current transformer mounted inside. A general view of the spiral FCG with coaxial load and calibrated current transformer installed inside is shown in Figure 4.

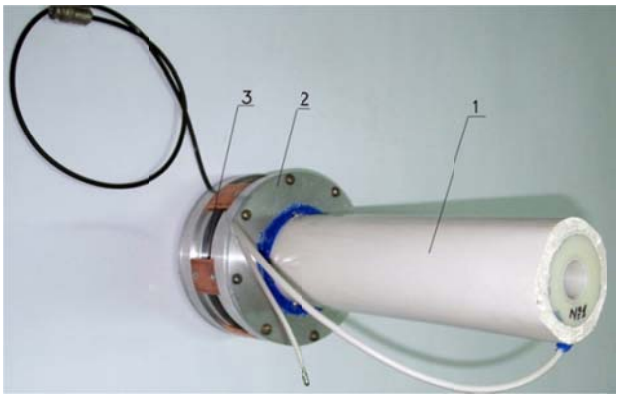
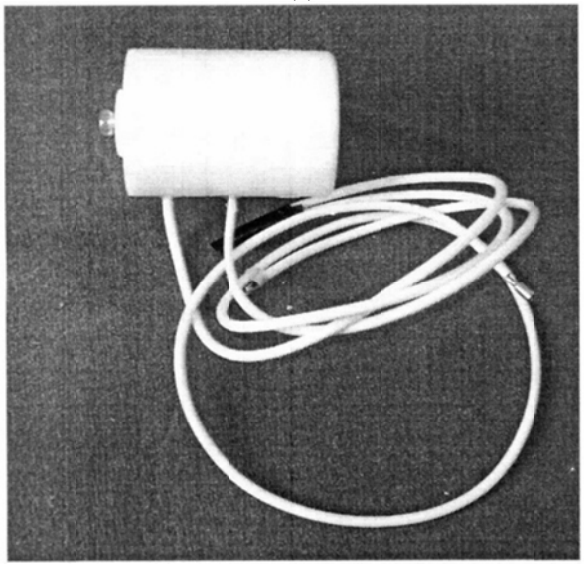


Figure 4. General view of spiral FCG with a coaxial load and current transformer; 1 is spiral FCG; 2 is 30 nHn coaxial load; and 3 is current transformer

B. FCG Seed Source

Three main components of the seed source are the: 1) primary energy source, 2) DC-DC upconverter and 3) high-voltage capacitor with an explosive closing switch. The prime energy source for the seed source is two 12 V batteries connected in series. A programmable 10W DC-DC voltage upconverter was used to generate 33 kV across the capacitive seed source. Two 40kV/0.03 µF pulsed capacitors provide a 250 A (300 A peak) current surge in the spiral FCG coil. The pulsed capacitors were connected in series with the FCG spiral coil through the explosive closing switch. A general view of the seed source capacitors and explosive closing switch are shown in Figures 5 (a,b), respectively.

(a)



(b)

Figure 5. a) General view of seed source capacitors; b) general view of explosive closing switch

C. High-Voltage Unit

A high voltage unit is installed at the FCG's output. It is a 2.6 µHn inductor storage unit and consists of a spiral coil filled with epoxy mixed with quartz sand. An Electro-explosive opening switch (EOS), wound with 0.05 mm copper wire, is mounted inside the inductor. The EOS is filled with quartz sand and connected to a high-pressure spark gap. This high pressure spark-gap is used to provide impedance matching with various potential loads. The EOS design is shown in Figure 6.

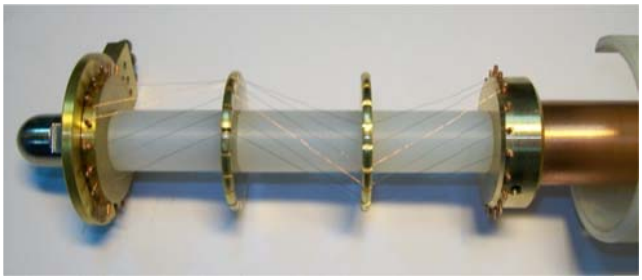


Figure 6. EOS General view.

III. EXPERIMENTAL VERIFICATION

Experimental verification has been performed for the seed source and FCG. The seed source has delivered a current pulse with an amplitude of 250 A and 14 J energy to the FCG spiral coil. The seed source capacitors were charged to 30 kV and then they were connected to the FCG spiral coil through the explosive closing switch.

This seed source pulse delivered 385 kA current to the FCG load; data is shown in Figure 7.

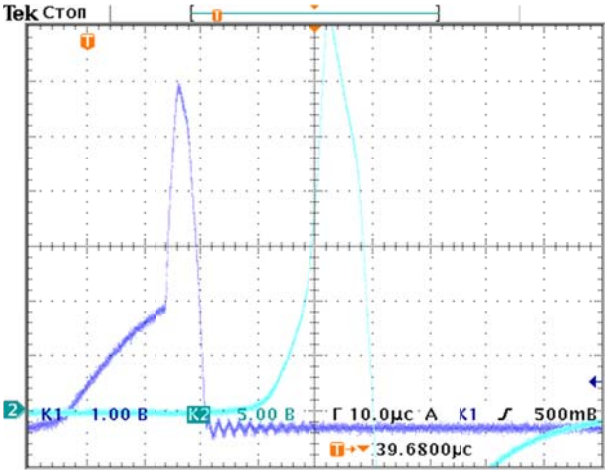


Figure 7. Seed source current waveform (dark blue trace); FCG current waveform (light blue trace)

The FCG's delivered 450-500 kV to a resistive load, through the EOS switch. The waveform produced by this power source depended on the load characteristics. The FCG was mounted inside a stainless steel casing, off-center by 20 mm. In order to minimize the influence of the casing on FCG operation, a longitudinal slot was cut in the casing's side and filled with an epoxy. Additional experimental verification has shown that the casings influence can be minimized for this particular design.

IV. SUMMARY

A self-contained, compact, pulsed high voltage source based on a small spiral FCG has been developed and experimentally verified. This source has been proven to be able to produce high voltage pulses with amplitudes of 450-500 kV magnitude and total energy values of 1kJ -1.2 kJ per pulse. These FCGs have a total length of 600 mm and a diameter of 143 mm. These sources have been shown to operate either with a resistive or a complex load.

V. REFERENCES

[1] Larry L. Altgilbers, Jason Baird, Bruce L. Freeman. Christopher S. Lynch et al., "Explosive Pulsed Power", World Scientific, 2010.

[2] J.C. Hernandez; A.L. Neuber; M.G. Lesserman; J.C. Dickens and M. Kristiansen "Compact FCG Driven Inductive Energy Storage system" , Proc. Megagauss-10 Berlin, 2004, pp. 144-147.